DESIGN OF A RESERVOIR FOR AN ARMY CANTONMENT OF 40,000 MEN

BY

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ARMOUR INSTITUTE OF TECHNOLOGY

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THE DESIGN OF A RESERVOIR FOR AN ARMY CANTONMENT OF 40,000 MEN

A THESIS

PRESENTED BY

BLOIS BERT CRAMER

TO THE

PRESIDENT AND FACULTY

OF

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FOR THE DEGREE OF

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IN

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FOREWORD.

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The author desires to express his gratitude to Professor Alfred E. Phillips and Assistant Professor John C. Penn, for their kind advice and suggestions on this Thesis.

Chicago, Illinois, May, 1918. B.B.C.

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INTRODUCTION.

The purpose of this thesis is to present a design for a reservoir for a National Army Cantonment of Forty Thousand Men.

It will be assumed that the reservoir is to be built in as short a time as possible, under war conditions, and that the cost of same will be as small as possible, for the given requirements, in order that the government funds may be touched upon as lightly as possible.

The source of the water supply and the location of the pumps for supplying water to the reservoir will be considered as located six miles from the reservoir site.

The water will flow by gravity from the reservoir into the distribution system.

The details of the water distribution through out the cantonment will not be touched

upon.

The thesis shall consist of a drawing of the design and the design itself.

The reservoir shall be designed to contain one and one-half days supply of water for the cantonment in order to allow one half day for repairs on pumps or on the supply line from the pumps to the reservoir.

The entire design is based upon the allowance per capita of 55 gallons per day of 24 hours. This estimate of water consumption was assumed after reading Dabney H. Maury's article on "Water Supply Specifications for National Army Cantonments reviewed." This article appeared in the Engineering News Record for January 3, 1918. Mr. Dabney Maury is Consulting Engineer for Water-Works at office of Cantonment Construction, Washington, D.C.

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THE DESIGN OF A RESERVOIR FOR AN ARMY CANTONMENT OF 40,000 MEN.

Explanation for giving Maury's Article with general specifications for National Army Cantonment.

In the design of a reservoir and water-works system for a cantonment or any large group of individuals, the first point to be determined is the quantity of water to be supplied to each person per day. In looking for data upon the above point the author happened to notice in Engineering News-Record of January 3, 1918, an article by Dabney H. Maury on "Water-Supply Specifications for National Army Cantonments Reviewed."

The data in the above article was the best obtainable on "Per Capita Consumption in Cantonments" and as the author used the above data in the design of the reservoir of this thesis, a rewriting of Dabney Maury's Article, and the Specifications contained therein will follow.

GENERAL SPECIFICATIONS FOR WATER SUPPLY OF NATIONAL CANTONMENTS.

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QUALITY: 1. The water supply as delivered into the distribution system at the cantonments should at all times be clear and free from sediment. It should not contain objectionable quantities of iron, manganese or other mineral constituents. Above all, it must be absolutely safe from a sanitary standpoint. During the construction period, great care must be taken to see that the water supply shall be maintained at all times in safe and sanitary condition.

QUANTITY: 2. The general specifications as to quantity of water necessary,as hereinafter given in Articles 3, 4 and 5, are based on the assumption that certain administrative rules for the purpose of checking waste will be established and strictly enforced with the limitations of military requirements, as follows: (a) All fixtures shall be shut off when not in actual use; (b) the fire drill regulations

shall make it the definite duty of certain designated individuals to shut off, as soon as fire alarm is sounded, every fixture from which water may be drawn for purposes other than fire-fighting, except those necessary for cooking purposes; (c) The several brigade units in each cantonment shall make use of the showers at different hours, so that the very heavy peak load resulting from the simultaneous use of all of the showers may be avoided; (d) The use of water for sprinkling roadways and grounds, and for the animals, shall be so timed, as not to coincide with the peaks resulting from the heavy draught for the showers.

Failure to enforce such rules will render inadequate all of the principal component parts of the entire water supply, fire protection and sewerage systems and will be dangerous in case of fire. These systems as designed are of ample capacity for all legitimate uses.

3. No matter what may be the source of supply, provision must be made to deliver at the cantonment site, at all seasons of the year and at all hours of the day, water at a rate of at least 55 gallons per capita per day for each man in the cantonment. For example, for a cantonment of 36,000 men, the daily supply should be not less than 2,000,000 gallons per day, equivalent to about 1400 gallons per minute; and for a cantonment of 45,000 men, the supply should not be less than 2,500,000 gallons per 24 hours, equivalent to about 1750 gallons per minute.

4. Provision must be made at the cantonment site, either through storage or otherwise, to furnish water to the distribution mains of the cantonment at all times, on three minutes' notice, and for a period of one hour, at rates 2.85 times as great as those just above specified; that is to say, at a rate of 4000 gallons per minute for one hour for a cantonment of 36,000 men and at a rate of 5000 gallons per minute for

one hour for a cantonment of 45,000 men.

5. The foregoing rates are intended in each case, to include the water supply required for horses and mules and for sprinkling and miscellaneous uses.

PRESSURE SPECIFICATIONS.

PRESSURE: 6. The water supply should enter the distribution mains of the cantonment at a pressure of not less than 60 nor more than 85 pounds per square inch. In cantonments of less than 40,000 men, and where the topography is fairly level, and where no buildings occupy ground much higher than the point at which the water enters the distribution mains, pressures not greatly in excess of 60 pounds will be sufficient. When, however, the cantonment houses more than 40,000 men, or when some of the buildings are on higher ground than the point at which the water enters the distribution, then higher pressures will be necessary in order to give proper domestic and fire service. These pressures are limited to about 85 pounds because of the fact that most of the wood stave pipe which will be used will be designed for working pressures of about that amount.

7. Because of limited appropriations it will be necessary to use wood stave pipe for the distribution mains to the extent that it may be possible to secure this pipe within the time available, This pipe will be of the machine-wound type, so that the pipe may be shipped all ready made up; and whenever possible it will be desirable to have men from the respective pipe factories on the ground to assist in the work of pipe laying.

8. On the typical water and sewerage plan, general plan, the layout of the water mains is shown. While the general location of the several units is subject to change to suit the topography of the various cantonment sites, the layout of the water mains in each unit should be adhered to as closely as possible, as the entire layout of all the service pipes for each unit, and the purchase orders for the pipes and fittings,will be based on locating the water mains as shown in the plans.

9. It will be noted from the typical water and sewerage plan that there are in every case two lines of water mains running the length of the cantonment. If the supply be delivered into the distribution system at one end of the line of units, there should be two mains leading from the supply thru the line of units and looped together at the far end. If the water enters at or near the center of the cantonment, then the two mains which run the length of the cantonment should be looped at each end.

10. Provided always that the initial pressures hereinbefore specified in Article 6, are at all times available, and provided further that the spaces between the separate units are not materially greater than those shown in the typical general plan, and assuming that there will be no elevated storage available, then if the supply be delivered at one end, the cantonment will require two 12 inch mains running throughout its length, while in a cantonment with center feed these two mains will be 10 inches. If,,however,

elevated storage can be obtained, sufficient in amount to tide over the peak loads hereinbefore specified, in Article 4, and at elevations corresponding to the pressures specified in Article 5, and so located with regard to the general layout, of the cantonment and especially with regard to the point of delivery of the supply to the distribution mains, that the elevated storage may be considered as a second source of supply, fed from the mains from a different direction, then the friction losses through the mains will be considerably reduced, and it may thus become possible to use mains of smaller sizes than those hereinbefore specified in this article. Typical details of the connections from supply to distribution system in each case are shown on the construction details for water.

REWRITING OF DABNEY H. MAURY'S ARTICLE.

"In the design of the water-works systems for the cantonments, the first point to be determined was naturally the quantity of water to be supplied. This was basic, and entered into every part of the design.

The considerations which affected the problem were, on the one hand, the desire to provide a supply of water sufficient in the practical operation of the cantonment, for every reasonable requirement of the troops, for domestic use as well as for proper fire protection; and, on the other hand, the limited appropriations, the enormous prices of materials, and labor, the difficulty of obtaining on short notice as much of either as was required for the simultaneous construction of 16 camps to house about 40,000 troops each, and, above all, the absolute necessity for haste.

It was at once recognized that some leakage and waste would be unavoidable; at the

same time, it was believed that the concentration of all the water fixtures in lavatories, where from forty to seventy outlets could be inspected almost at a glance, and the fact that, under military discipline, proper administrative rules could be enforced would combine to make it an easy matter to reduce leakage and waste to relatively small amounts.

More consideration was given to the determination of the proper allowance of water than to any other question, and Messrs. Leonard Metcalf, of Boston, and George W. Fuller, of New York, who were advisory to the Committee on Emergency Construction and Engineering of the General Munitions Board; Clarence Goldsmith and W. M. Johnson, whose services were kindly loaned to the Office of Cantonment Construction by the National Board of Fire Underwriters and Captain Leonard S. Doten, Q.M.R.C., who has for years, had much to do with the design of the water works and sewerage systems in the regular

army posts, all devoted, with the writer, much time to the consideration of this important and fundamental question.

The basis quantities having once been agreed upon, the writer then prepared the above General Specifications for Water-Supply which formed part of the first general Instructions to Constructing Quartermasters."

PER CAPITA ALLOWANCE NEARLY DOUBLE ALLIES.

Mr. Maury in his article continues: "The allowance of 55 gallons per capita per day includes an allowance of 15 gallons apiece for the horses and mules. As there is about one animal for every three men, the net allowance for the use of the men is 50 gallons apiece per day.

This is about 80 percent. more water on the average, than is supplied in the British, French, Belgium, German or Canadian cantonments

and is larger than the quantity recommended by Captain Francis C. Harrington in his paper on this subject, published in "Professional Memoirs, Corps of Engineers," Volume 8, No.39.

It is well recognized fact that Americans use, and waste, more water than any other nation; but there aremany cities in the United States where meters are in fairly general use, and in which the daily per capita consumption averages less than 50 gallons, including all water wasted, leakage in drains and service pipes, flushing sewers, sprinkling lawns and streets, public and private fountains, the water used by the fire department, and all sorts of industrial, commercial and manufacturing uses, these latter being often quite large in amount; in short, every drop of water that enters the distribution mains at the pumping station."

THREE CANTONMENTS USE LESS THAN 30 GALLONS.

Mr. Maury continues: "Reports so far

received from 14 National Army Cantonments and one National Guard Camp having a sewerage system and lavatory fixtures similar to those of the Army Cantonments, show that only four of these 15 camps are exceeding 55 gallons per capita per day, and that of the eleven camps which have not exceeded the allowance, three have actually used less than 30 gallons per capita per day, with plenty of water for everybody in camp.

A number of complaints of insufficient supply have been received. In one of these cases the complaints were wholly justified,but were due entirely to the fact that the yield of the wells,which had originally been entirely sufficient, suddenly fell off to far below the required amount, and more wells were authorized. In no other cantonment has the supply provided been less than the specified allowance.

In one camp, located in a cold climate the water used for steam heating, and for which no return system is provided, caused a loss

estimated at from 500,000 to 600,000 gallons per day. This, when coupled with a failure to confine leakage and waste to reasonable limits, compelled the sinking of additional wells.

One other camp complained of being unable to keep water in its reservoir, and installed additional wells, and also made an emergency connection with a polluted river. In this case there was actually a sufficient supply of well water for all legitimate purposes and had leakage and waste been checked, no shortage would have occured. The emergency connection with the river was promptly ordered removed.

The ease with which some of the cantonments are keeping their total consumption down below 30 gallons per capita, with plenty of water for evert one in camp, shows conclusively that the allowance of 55 gallons is a liberal one; and if the officer in charge of utilities in each camp be given the necessary men to keep

the fixtures in order, and the authority to enforce regulations against waste, the water consumption can and should be kept within that allowance.

It will be seen from the Pressure Specifications, that great flexibility was allowed. This was necessary in order to meet the varying topography and other local conditions, At the same time, they fixed definitely the location of mains, hydrants, and service pipes in each military unit, and the sizes of pipes to each building, and they also prescribed certain sizes of mains for each set of conditions which could reasonably be anticipated."

COMPUTING SIZE OF MAINS FOR PEAK LOAD.

Mr. Maury further states: "Assuming in turn each of these sets of conditions, computations were first made to determine the size of mains required to furnish adequate

domestic pressure and service at times of peak domestic load.

Other conputations were then made to determine the size of mains required to deliver a fire flow of 2000 gallons per minute at 50 pounds,at hydrants concentrated at the most distant part of the system, in addition to a distributed domestic load of one-quarter of the estimated domestic peak. If one of these computations called for larger mains than the other, the larger size was specified. The difficulty of securing standard rubber-lined hose, the fact that no building was more than two stories high, and consideration of friction losses, led to the decision to use 2-$\frac{5}{8}$ inch mill hose, with small nozzles, and unusually close spacing of hydrants. In general it may be said that for camps having end feed, the domestic requirements called for larger mains than did the fire departments, while for camps having center feed, the reverse was

true. In all of the camps it was possible to approximate the center-feed condition, and in many cases the mains could be looped at the ends. These advantages were at least partially offset by the fact that, because of broken topography at many of the sites selected, the various military units were often widely separated, thus greatly increasing the length of mains required.

In general, it may be stated that the National Army camps have, all things considered, higher standard of water supply and of fire protection than the average city of like size."

UNIT COST ONE FIFTH AVERAGE CITY WATER-WORKS.

Mr. Maury concludes: "It may also be stated that the cost of reproduction new of the average water-works system in a city of 40,000 inhabitants, at present prices for materials and labor, and exclusive of service connections, would average over $2,000,000, or more than

$50.00 per capita. As nearly as can be ascertained at present, the cost of the water works of the 16 National Army Cantonments, including service connections to within 5 feet of the buildings, has been less than $11.00 per capita, or say about one-fifth as great as the reproduction cost new today of the average municipal water-works system.

Perhaps 25 percent. of this great difference in cost of the entire system is due to the fact that about 70 percent. of the distribution mains have been wood stave pipe instead of cast iron pipe, the cost of wood-stave pipe being on the average about 60 percent. of that of cast iron pipe. The greater density of population in the camps has also contributed materially to reduce the cost of their water works. But when every possible allowance has been made the comparison of cost cannot be other than favorable to the camps.

Finally, and infinitely more important, is the time comparison. The time allowed for planning and completing a water works system for a city of 40,000 population would, under ordinary circumstances, be about three years; whereas, with the most difficult material, labor and transportation conditions ever known in this country, the water works for the 16 National Army contonments, have been planned and completed in a little over three months."

DETERMINATION OF DIMENSIONS OF RESERVOIR.

The per capita consumption will be taken as 55 gallons per 24 hour day. The reservoir which is to contain water for a cantonment of 40,000 men will be designed for 1½ days supply. The total volume of the water in reservoir must then be 55x40000x1.5=3,300,000 gallons. 1 cubic foot = 7.48 gallons.

Total volume in cubic feet is then 3,300,000 ÷ 7.48=442,000.

Assume the mean diameter to be 150'0".

The surface area of water is Πr^2=3.14 x 5625.= 17,700 square feet.

The depth of water will then be 442,000÷ 17700= 25'0"

Make the diameter 155'-0" from center to center of top surface of wall. Make the water depth at the wall 25'-0"

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CALCULATION OF LONGITUDINAL STEEL IN THE STEM.

Let C, B and A be points on inside of wall at depths of 8'-0", 16'-0" and 25'-0" below

the high water level, which is assumed as 1'0" beloww top of stem. Let H=height of reservoir in feet above section considered. Let D=diameter of reservoir in feet and A_H= area in square inches of horizontal steel per feet of height at section considered. The allowed unit stress, Fs, in steel per square inch will be 16,000 pounds per square inch. At any horizontal section the total tensile force, per foot height tending to rupture the reservoir on any diameter is 62.5 x H x D. Since the area of steel resisting this force is $2A_H$, we have $2A_H fs = 62.5\ H\ D$ or $A_H = (31.3 \times H \times D) \div fs$.

For a section of wall 1 foot above A, or above 25 feet water depth, $A_H = (31.3 \times 25 \times 155) \div 16000 = 7.34$ square inches steel per foot height above 25 feet depth.

For a section of wall 1 foot above B, or above 16 feet water depth, $A_H = (31.3 \times 16 \times 155) \div 16000 = 4.70$ square inches steel per foot height above 16 foot depth.

For a section of wall 1 foot above C, or above 8 foot water depth, A_H = (31.3 x 8 x 155) ÷ 16000 = 2.35 square inches steel required per foot height above 16 foot depth.

Total steel required from A to B = 7.34 x 9 = 66.06 square inches.

Total steel required from B to C = 4-70 x 8 = 37.6 square inches.

Total steel required from C to D = 2.35 x 8 = 18.80 square inches.

SPACING OF LONGITUDINAL STEEL IN STEM.

There will be two vertical rows of horizontal steel in the stem and the front and back rows will be assumed to take the same tension. The spacing of steel will be as follows: Area steel, 1 foot above 25 foot water depth = 7.34 square inches. Use $1\frac{3}{8}$ inch square bars spaced 6 inch centers. Area = 7.56 square inches ∴O.K. Area Steel 1 foot above 16 foot water depth = 4.70 square inches. Use $1\frac{1}{8}$ inch square

bars spaced 6 inch centers. Area = 5.06 square inches ∴ O.K. Area steel 1 foot above 8 foot water depth = 2.35 square inches. Use 15/16ths inch square bars spaced 9½ inch centers. Area = 2.34 square inches .: O.K. The same steel and spacing will be used in A E as is used in A B.

RATIO OF STEEL TO CONCRETE IN STEM.

The section shown in the General Drawing will be assumed: The area of concrete in the stem is then ½ x 26 x 12 x 48 = 7488 square inches. The total horizontal steel in the steam to take the water pressure is 122.46 square inches. Usually from 1 to 1½ per cent. of the area of concrete in the stem is steel.

If the ratio of steel to concrete is taken at 1½%, the required area of steel would be 7488 ÷.015 = 112.32 square inches. The actual area of steel checks up with the usual assumed ratio of steel to concrete and is therefore O.K.

TEMPERATURE REINFORCEMENT IN STEM.

THE only temperature reinforcement in the stem will be vertical and will be assumed to be 0.4% of the average horizontal area per foot length of retaining wall. Try 2 angles -3" x 3" x ½". Space the ladders 3'0" center to center. Connect the two angles of each ladder with horizontal bars ½" x 2½". The theoretical area of steel required is 2 x 3 x 144 x .004 = 3,456 square inches in 3 feet. The area of 2 - 3" x 3" x ½" angles is 5.0 square inches. As these angles will be stiff enough to hold up the horizontal steel without bending, and as the percent. area of steel is sufficient, these angles will be used.

BEARING PRESSURE OF WALL UPON SOIL.

A soil having a bearing power equivalent to that of Chicago soil (ie. 3000 pounds per square foot) will be assumed for the entire

RESERVOIR SITE. The section assumed has a breadth of 7' 6". The weight of a one foot section of wall with the roof upon it is 19062 pounds. The actual bearing on the soil is 19062 ÷ 7.5 = 2540 pounds per square foot. As this is less than the assumed bearing power the section width chosen is O.K.

REINFORCEMENT IN REAR FOOTING.

Take center of moments for bending moment in rear footing is at E. The total bending moment acting downward is caused by the weight of water above rear footing, the weight of rear footing and the weight of the floor above rear footing. These forces give

Bending Moment = (5750) (1.75) = 10050 foot pounds.

Bending Moment =(920) (1.66) = 1530 foot pounds.

Bending Moment =(525) (1.66) = 870 foot pounds.

TOTAL BENDING MOMENT ACTING DOWNWARD = 12450 foot pounds.

This Bending Moment is opposed by the Bending Moment due to the resisting force of the soil, which direction is upward. The acting pressure on soil, which is 2540 pounds per square foot, equals the resisting force of the soil. The total resisting area of the rear part of footing is 3.5 square feet. The total resisting force is therefore 3.5 x 2540 = 8900 pounds. The lever arm of this resistance is 1.75 feet. The bending moment due to this resistance is 8,900 x 1.75 = 15600 foot pounds which acts upward. The resulting Bending Moment is 15600 - 12450 = 3150 foot pounds or 37,800 inch pounds. This is the minimum Bending Moment and occurs when the reservoir is full of water. The maximum Bending Moment occurs when the reservoir is empty. The Bending Moment then acting downward is:-

Bending Moment = (920)(1.66) = 1530 foot pounds
Bending Moment = (525)(1.66) = 870 foot pounds
2400 foot pounds

acting downward.

The total resisting moment is 8900 x 1.75 = 15600 foot pounds. The maximum resulting Bending Moment is 15600 - 2400 = 13200 foot pounds, or (13200) (12) = 158,500 inch pounds acting upward.

$T = M \div j\ d.$

Where T = total tension in steel or = $f_s\ a$

then $a_s = \frac{T}{f_s}$.

a = area steel

f_s = allowed stress in steel = 16000 pounds
per square inch.

d = depth of footing.

j = .874 for 650 pound concrete.

Let the center of steel in rear footing be 3" from the top of rear footing.

$T = 158500 \div (.874)\ (21) = 8620$ pounds.

$a_s = 8620 \div 16000 = .538$ square inches per linear
foot wall.

Use $\frac{9}{16}$" round rods spaced 5½" center to center.

Then a = .54 square inches.

From Hool. $p = \frac{a_s}{bd}$ Where d is depth to steel

in rear footing, and b is breadth which is taken as one foot, as one foot of wall is considered, $d = 24" - 3" = 21"$.

$p = a_s \div b\,d = .54 \div (12 \times 21) = .00214$.

Let $n = 15$ = ratio of Es to Ec. Where Es is the modulus of elasticity of steel and Ec is the modulus of elasticity of concrete.

From Hool's "Reinforced Concrete Construction."

$k = (2\,p\,n + (p\,n)^2)^{\frac{1}{2}} - p\,n$

$fc = 2\,M \div k\,j\,b\,d^2$

p = "steel ratio" = the ratio of the area of steel to the area of concrete.

fc = Maximum allowed unit stress in concrete which is 650 poinds per square inch.

M=Bending Moment.

k = proportionate depth of neutral axis from below the compression surface.

$k = (2\,(.00214)\,(15) + (.0021 \times 15)^2)^{\frac{1}{2}} - 15 \times .0021 = .218$.

$fc = 2\,M \div kjbd^2 = 2\,(158500) \div (21)^2\,(12)\,(.874)\,(.218) = 314$ pounds per square inch.

This is well within the allowed stress and therefore is O.K.

REINFORCEMENT IN FRONT FOOTING.

Earth will be assumed to be piled behind the wall to a depth of $\frac{2}{3}$ the entire height of wall or 20'-0" above the bottom of the wall footing. Let the weights of clay and concrete be taken at 100 pounds per cubic foot and 150 pounds per cubic foot respectively. The total weight of the earth above the front footing = (18) (100) = 1800 pounds. The weight of concrete in the front footing = (2) (1) (150) = 300 pounds. The lever arm of the two weights is 6", the center of moments being 1 foot from toe of wall. The Bending Moment due to the weight of concrete and earth fill is (1800 -- 300) (.5) = 1050 foot pounds acting down. The soil offers a resistance of 2540 per square foot or a total resistance of 2540 x 1 = 2540 pounds as the width of the front footing is 1 foot. The Bending Moment due to the resistance of the soil is therefore 2540 x .5 = 1270 foot pounds. This Bending Moment acts upward and is

opposed by the downard Bending Moment.

1270 -- 1050 = 220 foot pounds = 2640 inch pounds is the resulting Bending Moment in front footing.

$T = M \div j\,d = 2640 \div (.874)\ (21) = 144$ pounds.

$A_s = T \div F_s = 144 \div 16000 = .009$ square inches, or say .01 square inch per linear foot of wall. This is practically nothing, but ¼" round rods will be put in the bottom of the front footing and will be spaced 1'-8" center to center. Then $A_s = .03$ square inches per linear foot of wall.

$$p = A_s \div bd = .03 \div (21)\ (12) = .00012$$

$$K = \left[2\ (.00012)\ (15) + (.00012 \times 15)^2\right]^{\frac{1}{2}} -- (00012)\ (15) = .0582.$$

$$f_c = 2\ (2640) \div (.874)\ (.058)\ (12)\ (21)^2 =$$

19.7 pounds per square inch. Therefore the above spacing is O.K.

DESIGN OF FOOTINGS FOR PIERS.

The weight of redwood will be taken at 38 pounds per cubic foot. The snow load for the roof will be assumed at 5 pounds per square foot. The total weight to be supported by the soil under each pier is as follows:-

Sheeting - 15.5 x 15.5 x (38÷12) = 758 pounds

Snow load = 15.5 x 15.5 x 5 = 1200 pounds.

8-2" x 10" - 18'-0" joists = (8x2x10x18x12x38)÷ 1728 = 760 pounds.

1-8"x8"-15'-6" red wood cap = (8x8x15.5x12x38) ÷ 1728 = 262 pounds.

1-8" x 8" - 29'-0" redwood post = (8x8x29x12x38) ÷ 1728 = 490 pounds.

Assume 10 cubic feet of concrete to each pier= 1500 pounds.

The total bearing on soil under each pier is then 5000 pounds. The bearing power of soil was assumed at 3000 pounds per square foot. The required bearing area is therefore 1.66 square feet. Make the base of the pier 2'-0" square.

WOOD STAVE PIPES TO BE USED THRU OUT ENTIRE SYSTEM

As war conditions are assumed, wood stave pipes will be cheaper and more readily obtainable, than iron pipes for the assumed site of this reservoir. Wood stave pipes will therefore be used through out the entire water works system, except for the 4-12"cast iron drain pipes that are laid under the reservoir floor. As no data on friction head in 30" or 36" wood stave pipes has been procurable, it will be assumed that the friction heads in these two sized pipes will be the same as for cast iron pipes. In the "Pocket Companion", issued by the Massillon Iron and Steel Co., Chicago, Ill., are tables giving friction head for the different sized pipes with different discharges thru them, in United States gallons per 24 hour day and these tables will be used in figuring the friction heads.

DETERMINATION OF SIZE OF PIPE FROM SOURCE OF SUPPLY TO THE RESERVOIR, AND ROUGH CALCULATION OF ENGINE HORSE POWER TO SUPPLY CANTONMENT WITH SUFFICIENT WATER.

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The following conditions are assumed:-

(1) Assume a 30" wood stave pipe, and assume the reservoir to be filled in 4 hours.

(2) Assume a 36" pipe and consider reservoir to be filled in 4 hours.

(3) Assume a 30" pipe, and consider the reservoir to be filled in 5 hours.

(4) Assume a 36" pipe, and consider the reservoir to be filled in 5 hours.

(1) The reservoir was designed to hold 1½ days' supply or to have a maximum capacity of supply of 2,200,000 gallons per 24 hour day. If the reservoir is to be filled in 4 hours, the rate of flow thru the pipe into the reservoir is 6 (2,200,000) = 13,200,000 gallons per day. Assume the distance from the power station to the reservoir is to be 6 miles. From "Pocket Companion" issued by the Massillon Iron and

Steel Co., Chicago, Ill., for a discharge thru a pipe of 13,248,000 gallons per 24 hour day, the friction head is 2,531 feet per1000 feet. 6 miles = 31680 feet. The friction head for 31680 feet = 31.68 x 2,531 = 80.2 feet. Assume the maximum elevation of water in the reservoir to be 85 feet above the elevation of water at the pumps. The total head the pumps have to act against is 80.2 + 85 = 165.2 feet. From the same table as gave the above friction head, the United States gallons discharged per minute = 9200 gallons. 7.5 gallons = (cubic foot). 9200 ÷ 7.5 = 1225 cubic feet per minute discharge. The total weight of water moved per minute is 1225 x 62.5 = 76500 pounds. The head moved against is 165.2 feet. The total work done per minute in moving the 76500 pounds water is 165.2 x 76,500 = 12, 620,000 foot pounds. The horse power required is therefore, foot pounds ÷ 33,000 = 12,620,000 ÷ 33,000 = 382.0

(2) If the reservoir is to be filled in 4 hours, thru a 36" pipe, the rate of discharge

thru it is 6 (2,200,000) = 13,200,000 gallons per 24 hour day. From "Pocket Companion" the friction head =1.043 foot per 1000 feet. The total friction head is therefore (1.043) x (31.68) = 33.0 feet. The total head due to friction and elevation is 85 + 33.0 = 118.0 feet. From "Pocket Companion," the discharge is 9200 gallons per minute. 9200 ÷ 7.5 = 1225 cubic feet per minute discharge. Weight of water moved per minute = 1225 x 62.5 ≈ 76500 pounds. The head moved against is 118 feet. The total work done per minute in moving water is 118 x 76500 = 9,040,000 foot pounds. The Horse Power required of the Pump is 9,040,000 ÷ 33000 = 274.0.

(3) If the reservoir is to be filled in 5 hours, thru a 30" pipe the rate of filling is 24 ÷ 5 = 4.8 x 2,200,000 = 10,560,000 gallons per 24 hour day From "Pocket Companion" for a discharge of 10,656,000 gallons per day, the friction head is 1,661 feet per 1000 foot. The friction head for 31680 feet is therefore 31.68 x 1,661 =52.6

feet. The total head to pump against = 52.6 + 85 = 137.6 feet. From the same table as gave the above friction head the discharge thru the 30" pipe in United States gallons per minute is 7400 gallons. The volume pumped per minute in cubic feet is 7400 ÷ 7.5 = 987 cubic feet. The weight of water moved per minute = 987 x 62.5 = 617000 pounds. The head moved thru is 137.6 feet. The total work done per minute in moving water is 137.6 x 61700 = 8,480,000 foot pounds. Horse Power = foot pounds ÷ 33000 = 8,480,000 ÷ 33000 = 257 Horse Power required at the pumps to take care of the necessary discharge thru the 30" pipe at the reservoir.

(4) If the time of filling the reservoir is again assumed at 5 hours with a 36" pipe, the rate of flow thru the pipe is 4.8 x 2,200,000 = 10,560,000 gallons per day. From table for 36" pipe with given discharge per day the friction head is =.668 feet per 1000 foot or .688 x 31,68 = 21.8 feet for the 6 miles of pipe. The total head

to pump against is 21.8 + 85 = 106.8 feet, From table, the discharge in United States Gallons per minute is 7400 gallons, cubic feet per minute = 7400 ÷ 7.5 = 987.0 Weight of water moved = 61700 pounds per minute. The head moved against is 106.8 feet. The total work done in moving water is 106.8 x 61700 = 6,580,000 foot pounds per minute. The Horse Power required at pumps to take care of the discharge at reservoir for a 36" pipe is 6,580,000 ÷ 33000 = 199 Horse Power.

From the four above conditions that were assumed, it is seen that it will probably be better to sacrifice the six inches of wood stave pipe in order to cut down the Horse Power to as low a figure as possible. An engine with a Horse Power as near 200 as possible will be installed. The efficiency of the engines or hourse has to be taken into consideration.

SIZE OF PIPE TO FEED DISTRIBUTION MAINS.

As it is not the purpose in this thesis to go into the details of determining the sizes of the pipes thru out the distribution system a

a 36 inch wood stave pipe will be assumed at the reservoir site to take care of the necessary discharge and to give a minimum pressure in the distribution mains of 75 pounds and a maximum pressure of 85 pounds per square inch.

ROOF.

The roof shall consist of Redwood caps, spaced 15'--6" center to center, supported upon concrete walls. At right angles to these 2" x 10" x 18'-0" Redwood Tarred Stringers will be laid with a spacing center to center of 18". One by six inch sheeting will be laid upon the stringers and over this will be nailed double ply standard roofing. The roof shall have a slope of 1" in 38¾" or the center post shall be 2'0" above top of reinforced concrete wall. The roof shall project 1'-6" beyond the center of the top of the wall.

SCREENING.

The spaces at the top of the wall between

the caps, the stringers and the wall top, shall be screened with galvanized iron wire screens. The fit of these screens must be as nearly perfect as possible to prevent refuse and insects from getting into the reservoir.

VENTILATOR AT TOP OF ROOF.

A ventilator shall be built at the top of the roof to prevent the collection of foul air above the top of the wall. The ventilator shall be 4' 0" square and it will also be screened with galvanized iron wire screens with perfect fit.

FLOOR.

The floor shall consist of a four inch layer of sand, and gravel, upon which is laid two four inch concrete slabs. A thin layer of asphaltic water proofing materal is laid, while hot, upon the lower slab, after which the top slab is laid upon the asphaltic material. The concrete floor shall consist of a 1:2:3 mixture

to insure water proofness. The top slab shall be covered with a layer of 1:1½ mortar ⅜" thick to further insure water proofness. Both slabs shall be reinforced with ½" square twisted bars spaced 1'0" centers both ways, The steel shall be placed 1" from the bottom of each slab. The floor shall be tied to the wall with ¾" square bars 7'0" long, spaced 2'0" centers. One half the 7' 0" length will be imbedded in the wall when built and the other half shall be imbedded into the lower slab, when laid. The reinforcement in the slabs shall extend to the quarter points in the adjacent panels. Make the floor panels 15' 6" square. The edges of the slabs are separated from the piers and retaining wall by a 1 inch asphaltum-filled, hot poured joint. The surface of the shoulders of the piers are to be left rough to give a firm bond to the asphaltic preparation.

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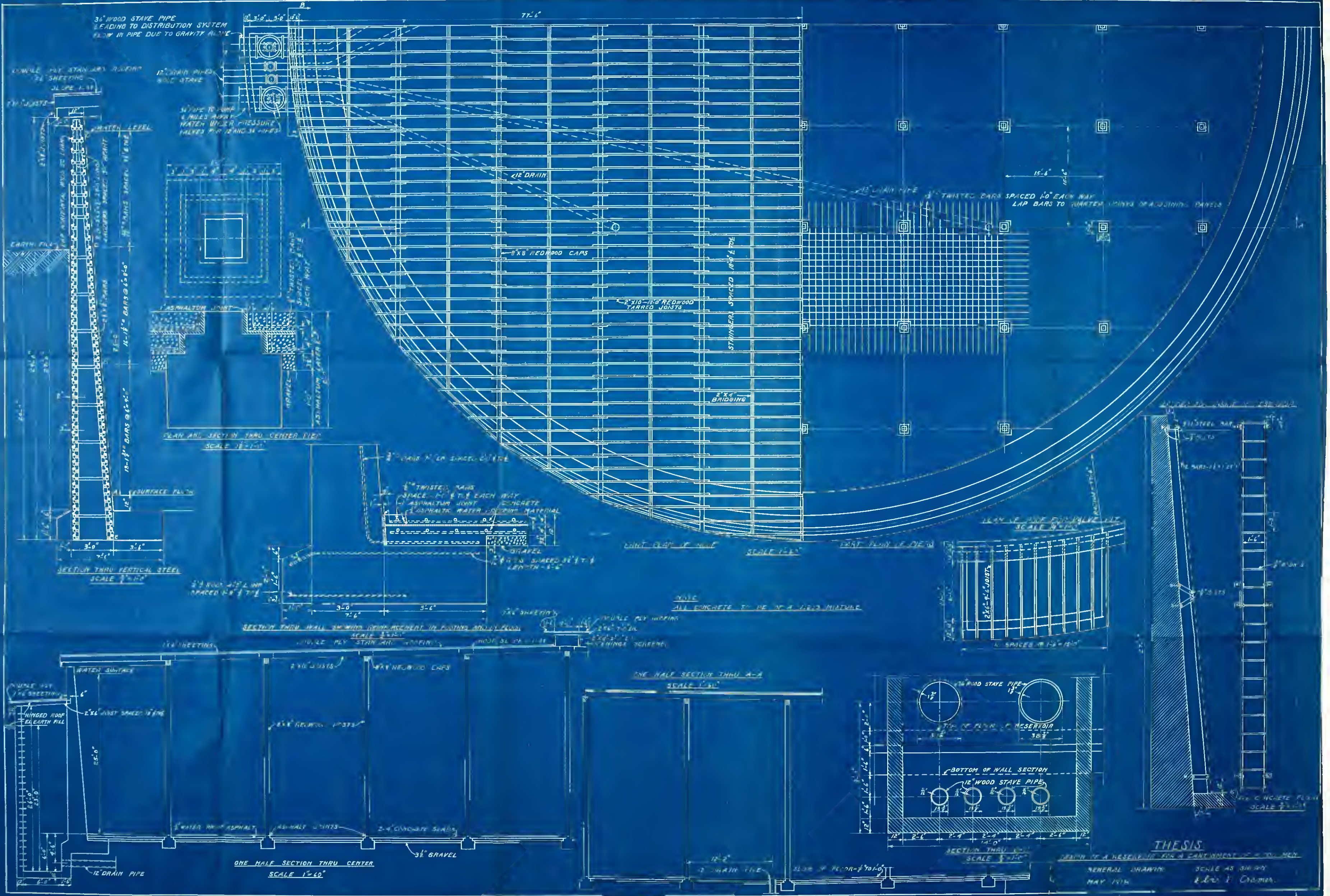
36" WOOD STAVE PIPE
LEADING TO DISTRIBUTION SYSTEM
FLOW IN PIPE DUE TO GRAVITY ALONE
12" DRAIN PIPE WOOD STAVE
36" PIPE TO PUMP 4 MILES AWAY WATER UNDER PRESSURE VALVES FOR 12 AND 36 PIPES
SLOPE 1-48
WATER LEVEL
EARTH FILL
SURFACE FLOOR
3'-0"
3'-6"
SECTION THRU VERTICAL STEEL
ASPHALTUM JOINT
GRAVEL
PLAN AND SECTION THRU CENTER PIER
77'-6"
12" DRAIN
8"x8" REDWOOD CAPS
2"x10"-12'-0" REDWOOD TARRED JOISTS
STRINGERS SPACED 16'-0" C TO C
2"x4" BRIDGING
15'-6"
12" DRAIN PIPE
TWISTED BARS SPACED 1'-0" EACH WAY
LAP BARS TO QUARTER POINTS OF ADJOINING PANELS
TWISTED BARS SPACED EACH WAY
ASPHALTUM JOINT
CONCRETE
ASPHALTIC WATER PROOFING MATERIAL
GRAVEL
7'-6"
SECTION THRU WALL SHOWING REINFORCEMENT IN FOOTING AND IN FLOOR
PART PLAN OF ROOF
SCALE 1"=8'-0"
PART PLAN OF PIERS
NOTE
ALL CONCRETE TO BE OF A 1:2:3 MIXTURE
DOUBLE PLY WOOFING
PLAN OF ROOF EDGE AT VALVE PIT
2"x6"-4'-0" JOISTS
SPACES @ 1'-8"=15'-0"
ONE HALF SECTION THRU A-A
SCALE 1"=20'
DOUBLE PLY STANDARD ROOFING
1"x6" SHEETING
ROOF SLOPE 1:48
WATER SURFACE
HINGED ROOF
EL EARTH FILL
2"x6" JOIST SPACED 18" CTRS
2"x10" JOISTS
8"x8" REDWOOD CAPS
8"x8" REDWOOD POSTS
25'-0"
26'-0"
23'-0"
WATER PROOF ASPHALT
ASPHALT JOINTS
2-4" CONCRETE SLABS
3½" GRAVEL
12" DRAIN PIPE
ONE HALF SECTION THRU CENTER
SCALE 1"=60'
36" WOOD STAVE PIPE
TOP OF FLOOR OF RESERVOIR
38½"
BOTTOM OF WALL SECTION
12" WOOD STAVE PIPE
13½"
12"
2'-6"
2'-4"
14'-0"
SECTION THRU B-B
CONCRETE FLOOR

THESIS

DESIGN OF A RESERVOIR FOR A CANTONMENT OF [illegible] MEN

GENERAL DRAWING SCALE AS SHOWN

MAY 1918 Cramer.